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BILLINGS, MONTANA
AIR POLLUTANT EMISSION INVENTORY

ENVIRONMENTAL PROTECTION AGENCY
Air Pollution Control Office

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BILLINGS, MONTANA AREA AIR POLLUTANT EMISSION INVENTORY

Prepared by

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ENVIRONMENTAL PROTECTION AGENCY

Air Pollution Control Office

Division of Air Quality and Emission Data

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A summary of the emission inventory for the Billings, Montana Metropolitan Area is presented. The report provides estimates of the present levels of air pollutant emissions and status of their control. The pollutants which include sulfur oxides, particulates, carbon monoxide, hydrocarbons, and nitrogen oxides are delineated with respect to source type, season of the year, and geographical distribution within the area. The Study Area, which was chosen on the basis of the size and distribution of its population and its air pollution sources, consists of three counties. A grid coordinate system was used to show the geographical distribution of emissions within counties. All sources of emissions were classified into five categories: transportation, stationary fuel combustion, solid waste disposal, industrial processes, and evaporative losses.

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Particles
Carbon monoxide
Hydrocarbons
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Seasonal variations
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PREFACE

This report, which presents the results of an emission inventory for the Billings Area, is another in a series of surveys outlining the sources and emissions of air pollutants for major metropolitan areas in the United States of America. These surveys, conducted by the National Inventory of Air Pollutant Emissions and Control Branch of the Air Pollution Control Office, provide estimates of the present magnitude, extent and sources of air pollutant emissions and the status of their control in the Study Area. The pollutants which the reports consider include sulfur oxides, particulates, carbon monoxide, hydrocarbons, and nitrogen oxides. These pollutants are delineated with respect to source type, season of the year, and geographical distribution within the Study Area. The general procedure for the surveys is based upon the "rapid survey technique" for estimating air pollutant emissions.[1]

The reports are used to provide the basis of the engineering evaluation in the designation of Air Quality Control Regions. The reports are also included in a national emission inventory and will provide a basis for future air resource management.

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INTRODUCTION

This report is a summary of the Billings, Montana area air pollutant emission inventory conducted in April 1970. This emission inventory was based upon calendar year 1969; the data and emission estimates presented are representative of 1969 and should be considered as indicating the conditions as existed during that year.

The Study Area and its extent, which was chosen on the basis of the size and distribution of its population and its air pollution sources, consists of three counties. This area covers approximately 6,500 square miles and had a 1969 population estimation of 97,200.[2]

A grid coordinate system was used to show the geographical distribution of emissions within counties. The Study Area was subdivided into 35 grid zones ranging in size from 25 square kilometers in the heavily populated and industrialized areas to 1,600 square kilometers in the rural areas.

All sources of emissions were classified into five categories: transportation, stationary fuel combustion, solid waste disposal, industrial processes, and evaporative losses. Each of these source categories was divided into two subgroups, point sources and area sources. Facilities which emit large significant quantities of air pollutants were considered individually as point sources. The many remaining pollutant contributors such as motor vehicles, residential and commercial fuel users, small industries, and on-site refuse burning equipment were considered collectively as area sources. For this report, 21 individual sources were classified as point sources.

Emissions were estimated by using various indicators such as fuel consumption, refuse burning rates, vehicle miles, production data, and control efficiencies and emission factors relating these indicators to emission rates.[2] The factors represent average emission rates for a particular source category. Due to the fact that individual sources have inherent differences that cannot always be taken into consideration, discrepancies between the actual and estimated emissions are more likely in individual sources than in the total emissions for a source category.

As in all emission surveys, the data presented are estimates and should not be interpreted as absolute values. The estimates are in some cases partial totals due to the lack of emission factors and production or consumption data. Despite these limitations though, the emissions contained in this report are of sufficient accuracy and validity in defining the extent and distribution of the air pollution emissions in the Study Area.

SUMMARY

The annual emissions (tons) as estimated by the Billings Area Air Pollutant Emission Inventory are:

Sulfur Oxides	27,470
Particulates	15,300
Carbon Monoxides	114,130
Hydrocarbons	23,710
Nitrogen Oxides	19,140

The following is a brief description of the air pollutant emissions as presented in Tables 1A and 1B.

Sulfur Oxides: The largest portion of the sulfur oxides emitted came from industrial process losses which accounted for 83 percent of the total sulfur oxides. The combustion of fossil fuels by stationary sources accounted for an additional 15 percent of the sulfur oxides emitted. The remaining 3 percent was distributed under motor vehicles, and refuse disposal.

Particulates: The majority of the particulate emissions (60 percent) came from process losses. An additional 9 percent of the particulate losses came from stationary fuel combustion and 10 percent from transportation sources.

Carbon Monoxide: In most metropolitan areas the largest source of carbon monoxide emissions is from automobiles and other motor vehicles. This was not true in the Billings

Area because process losses contributed 52 percent of the carbon monoxide emitted annually. Transportation sources including road vehicles, railroad, and aircraft operations contributed 47 percent. The inefficient burning of solid wastes provides a small percentage of the total carbon monoxide emissions.

Hydrocarbons: Process losses were the primary source of hydrocarbon emissions accounting for over 55 percent of the total. Exhaust and evaporative losses (which includes losses from the gas tank, carburetor, and engine crankcase) from motor vehicles accounted for 28 percent of the total hydrocarbon emissions. Other smaller evaporative loss sources including gasoline storage and handling, industrial solvent usage, dry cleaning plants, and miscellaneous solvent usage collectively accounted for 16 percent of total emissions.

Nitrogen Oxides: Process losses contributed 45 percent of the total nitrogen oxide emissions while transportation contributed an additional 30 percent. The remaining 25 percent of the nitrogen oxides came mainly from the combustion of fuel in stationary sources.

TABLE 1A SUMMARY OF AIR POLLUTANT EMISSIONS IN STUDY AREA, 1969

Tons/Year

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation					
Road Vehicles	280	460	45,350	3,820	3,370
Other	310	1,160	8,730	2,770	2,300
Subtotal	590	1,620	54,080	6,590	5,670
Stationary Fuel Combustion					
Industry	500	170	10	10	1,020
Steam-Electric Utility	3,470	1,050	80	40	3,310
Residential	40	50	60	10	280
Commercial and Institutional	30	40	40	10	180
Subtotal	4,040	1,310	190	70	4,790
Refuse Disposal					
Incineration	20	10	250	10	50
Open Burning	N*	40	220	90	30
Subtotal	20	50	470	100	80
Process Losses	22,820	12,320	59,390	13,030	8,600
Evaporative Losses	--	--	--	3,920	--
GRAND TOTAL	27,470	15,300	114,130	23,710	19,140

*N = negligible

TABLE 1B SUMMARY OF AIR POLLUTANT EMISSIONS IN STUDY AREA, 1969

10^3 kg/year

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation					
Motor Vehicles	250	420	41,140	3,470	3,060
Other	280	1,050	7,920	2,510	2,090
Subtotal	530	1,470	49,060	5,980	5,150
Stationary Fuel Combustion					
Industrial	450	150	10	10	930
Steam-Electric	3,150	950	70	40	3,000
Residential	40	50	50	10	250
Commercial and Institutional	30	40	40	10	160
Subtotal	3,670	1,190	170	70	4,340
Refuse Disposal					
Incineration	20	10	230	10	50
Open Burning	N	40	200	80	30
Subtotal	20	50	430	90	80
Process Losses	20,700	11,180	53,880	11,820	7,800
Evaporative Losses	--	--	--	3,560	--
GRAND TOTAL	24,920	13,890	103,540	21,520	17,370

N - negligible

TABLE 2 PERCENTAGE CONTRIBUTION OF EACH SOURCE CATEGORY TO TOTAL EMISSIONS IN THE BILLINGS STUDY AREA

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation					
Motor Vehicles	1.0	3.0	39.8	16.1	17.6
Other	1.1	7.6	7.6	11.7	12.0
Subtotal	2.1	10.6	47.4	27.8	29.6
Stationary Fuel Combustion					
Industry	1.8	1.1	0.0	0.0	5.3
Steam-Electric	12.6	6.9	0.1	0.2	17.3
Residential	0.1	0.3	0.1	0.0	1.5
Commercial and Institutional	0.1	0.3	0.0	0.0	0.9
Subtotal	14.6	8.6	0.2	0.2	25.0
Refuse Disposal					
Incineration	0.1	0.1	0.2	0.0	0.3
Open Burning	0.1	0.3	0.2	0.4	0.2
Subtotal	0.2	0.4	0.4	0.4	0.5
Process Losses	83.1	80.4	52.0	55.1	44.9
Evaporative Losses	--	--	--	16.5	--
TOTAL	100	100	100	100	100

DESCRIPTION OF STUDY AREA

The Study Area for the emission survey of the Billings, Montana Area consists of three counties--Carbon, Stillwater and Yellowstone all in Montana. The three county area is located in the south-central part of Montana. Figure 1 shows the location of the Billings Study Area relative to other cities in its vicinity.

Figure 2 represents a more detailed drawing of the Billings Study Area showing the major urban areas. It should be pointed out that the boundaries of these areas do not correspond to city limits, but rather give a general outline of the major clusters of population. The Study Area occupies 6,500 square miles and contained an estimated 1969 population of 97,200, which is approximately a 5 percent increase since 1960 (Table 3). The population density map (Figure 3) shows the heaviest concentrations near the city of Billings.

TOPOGRAPHY[3]

The Billings Study Area is located in the borderline area between the Great Plains and the Rocky Mountains. The general elevation of the area around Billings is about 3,100 - 3,600 feet.

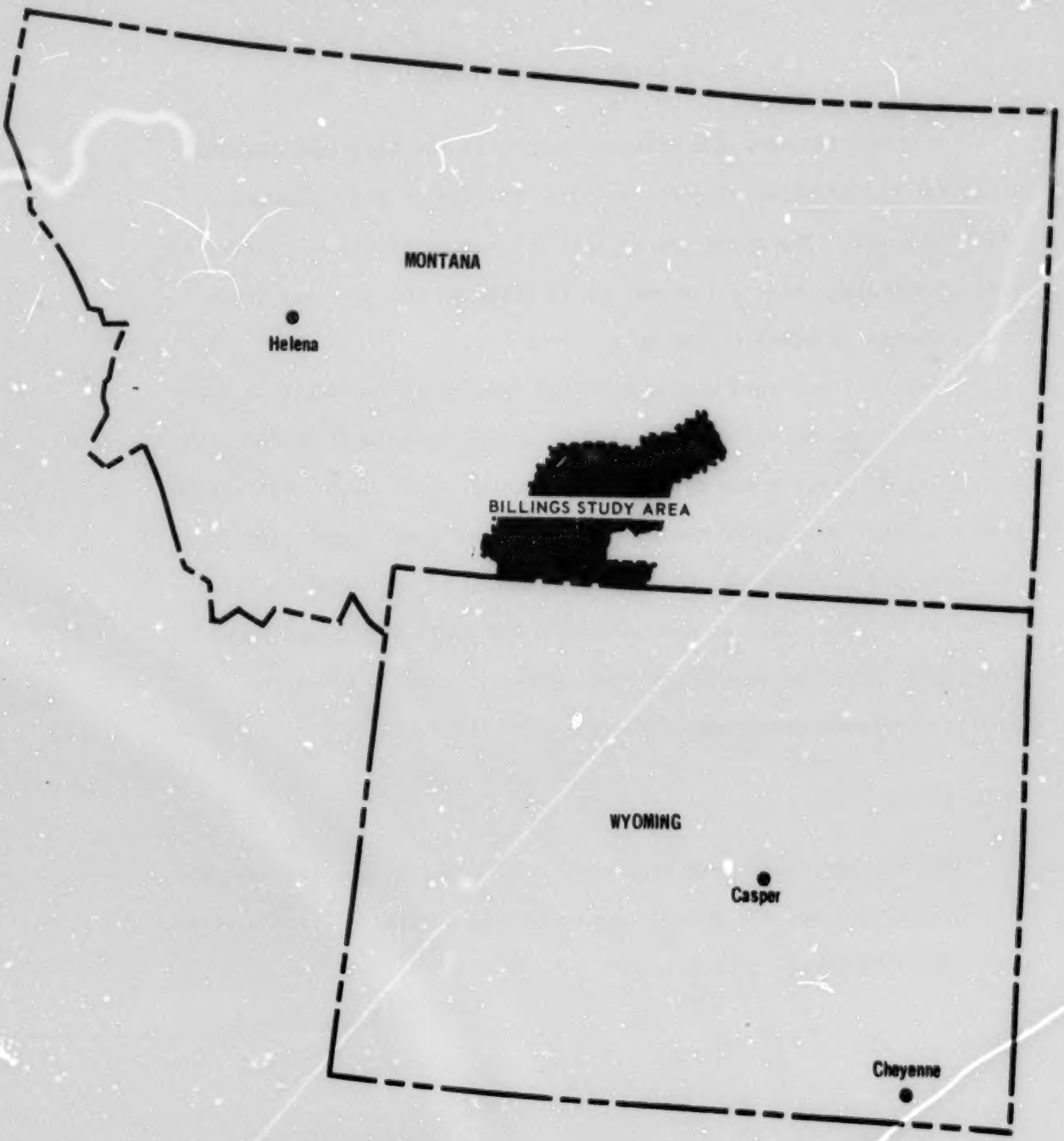

Figure 1. Billings study area and surrounding cities.

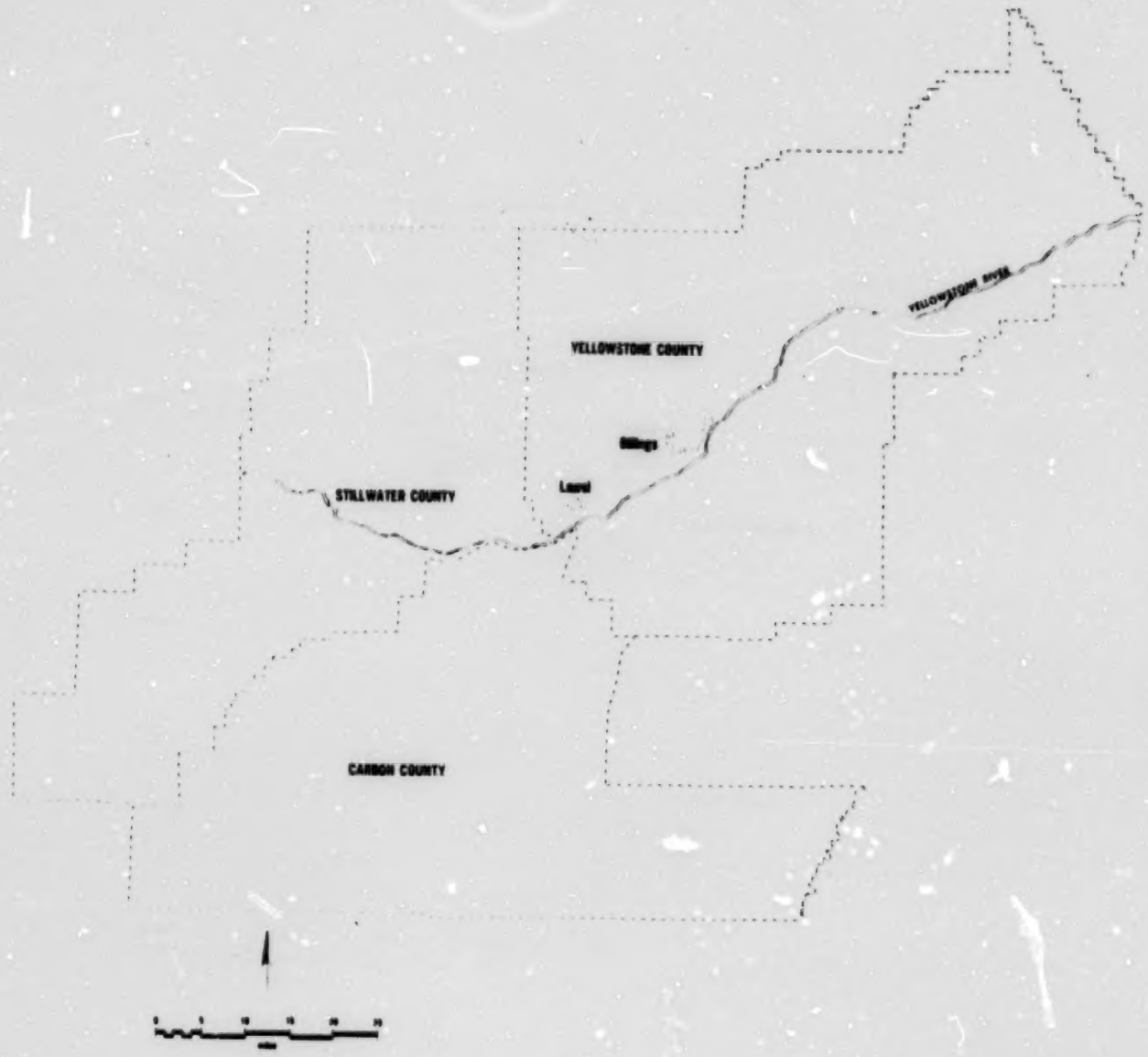

Figure 2. Detailed map of the Billings study area.

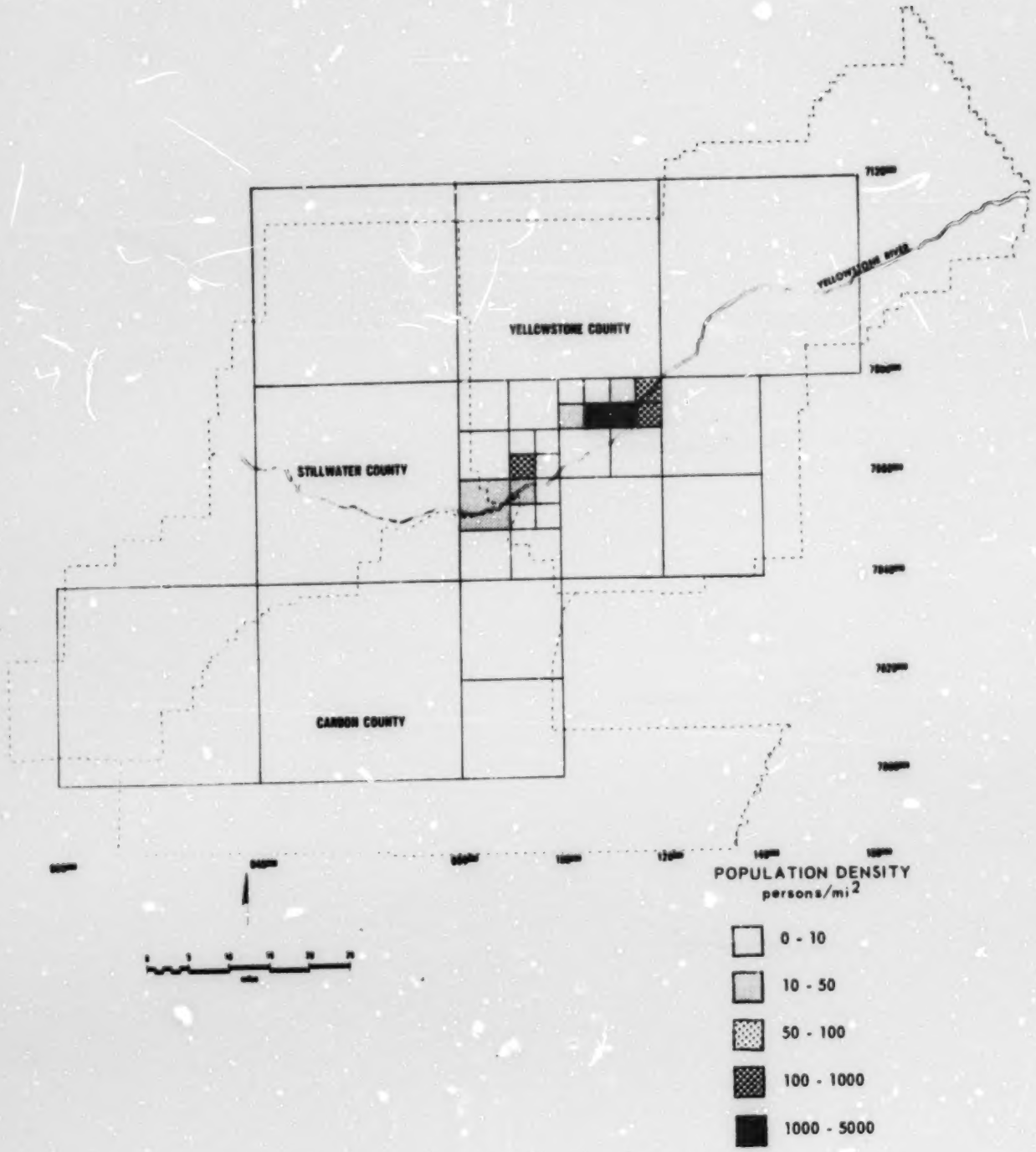

Figure 3. Population density for the Billings study area, 1969.

TABLE 3 AREA AND POPULATION CHARACTERISTICS FOR THE BILLINGS STUDY AREA

Political Jurisdiction	(Sq. Mi.) Land Area	Population 1960	Population 1969	Average Population Density (persons/mi) (1969)
Yellowstone County	2,642	79,016	85,900	32
Stillwater County	1,794	5,526	4,390	2
Carbon County	2,067	8,317	6,910	3

GRID COORDINATE SYSTEM

A grid coordinate system, based on the Universal Transverse Mercator Projection (UTM) was used in the Billings Study Area to indicate the geographical distribution of emissions. A map showing the grid coordinate system is presented in Figure 4.

The UTM System was chosen due to its advantages over other standard grid systems such as the Latitude-Longitude and State Plane Coordinate systems. The major advantages of this system are that (1) it is continuous across the country and is not hindered by political subdivisions, (2) the grids are of uniform size throughout the country, (3) it has world-wide use, and (4) the grids are square in shape--a necessary feature for use in meteorological dispersion models.

The Universal Transverse Mercator Projection is based upon the metric system. Each north-south and east-west grid line, as illustrated in Figure 4, is identified by a coordinate number expressed in meters. Each point source and grid is identified by the horizontal and vertical coordinates of their geographical center to the nearest 100 meters.

As shown in Figure 4, the Study Area was divided into 35 grids of 4 different sizes: 25, 100, 400 and 1,600 square kilometers. Grid zones of different sizes are used to limit the number of grid zones and yet allow a satisfactory definition of the geographical gradation of emissions. The majority of the emissions is usually concentrated in the populated and industrialized portion of a study area. Smaller grids are placed over these areas in order to reflect abrupt changes in emission within short distances.

The use of grid zones smaller than 25 square kilometers is not warranted because of the inherent inaccuracies in the data. Since only a small percentage of the total emissions occur in rural areas, large grid zones are normally used to show the distribution of emissions in these lightly populated portions of the Study Area.

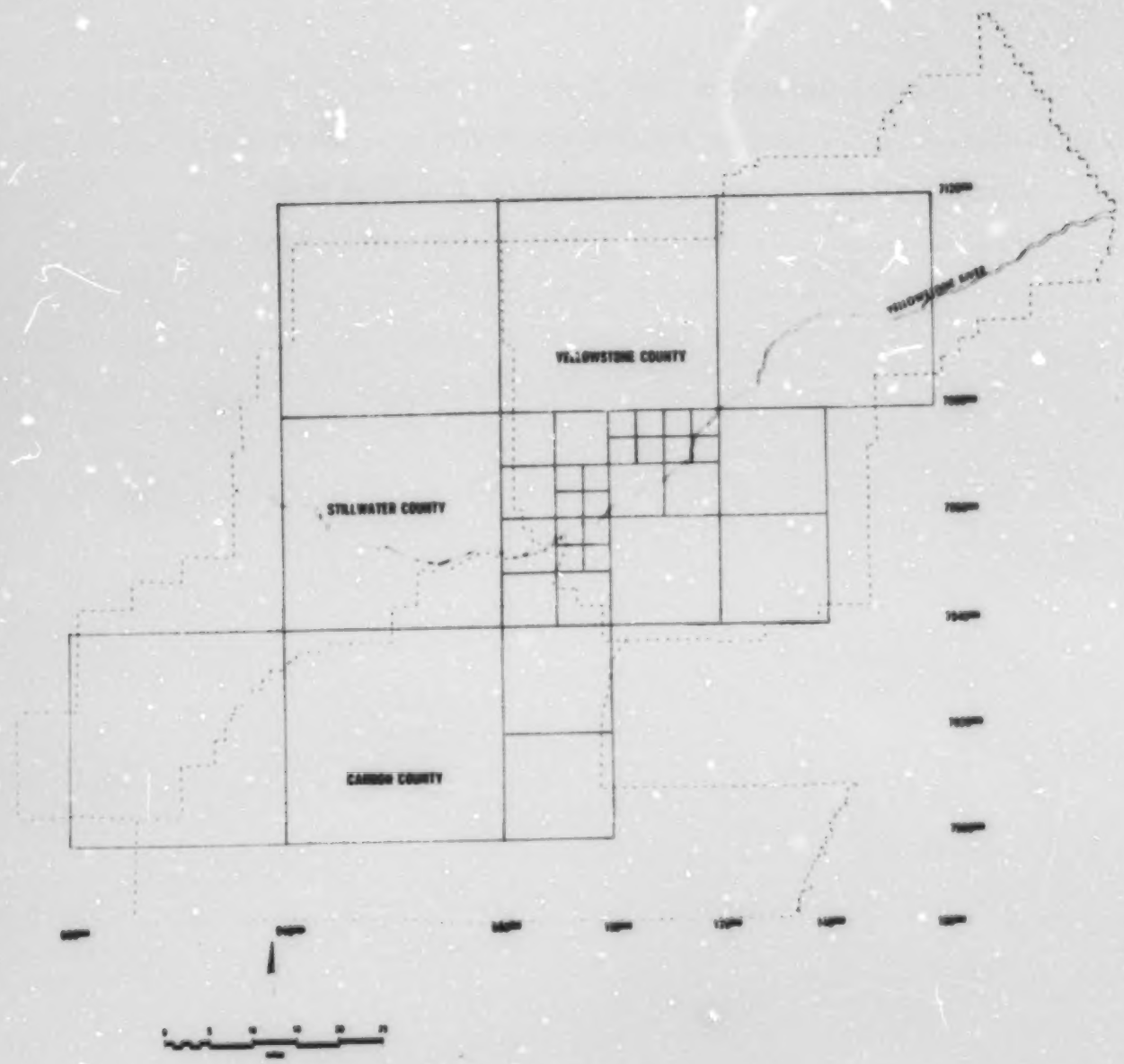

Figure 4. Grid coordinate system for the Billing study area.

EMISSIONS BY CATEGORY

For the purposes of compiling the basic data and emission estimates, the air pollutant sources were classified into the following five categories:

1. Stationary fuel combustion
2. Transportation
3. Solid waste disposal
4. Industrial processes
5. Evaporative losses

Each of these categories is considered individually in this section where data sources are given and methods of calculation discussed.

STATIONARY FUEL COMBUSTION

The stationary fuel combustion category is concerned with any fixed source which burns fuels for either space heating or process heating. The four primary sources in this category are industrial facilities, steam electric plants, residential housing and commercial and institutional establishments.

Table 5 presents a summary of the fuels consumed in the Study Area, and Table 6 provides an average chemical analysis of these fuels.

Data on the amounts of fuels used were obtained from local fuel suppliers and distributors, which were compared to totals provided by the local agency.

Steam-Electric Utility

METHODOLOGY: There is only one steam-electric power plant in the Study Area. Specific information on fuel combustion was obtained for

this plant. The primary fuel consumed was coal, although residual oil and natural gas were also used.

RESULTS: Emissions from this utility are included in Table 6. This category accounts for 64 percent of the sulfur oxides, 24 percent of the particulates, 14 percent of the carbon monoxide, 20 percent of the hydrocarbons and 37 percent of the nitrogen oxides in the Study Area from stationary fuel combustion.

Industrial

METHODOLOGY: Since in a rapid survey of industrial sources it is impossible to contact every plant, other techniques must be used to determine the contribution of industrial fuel combustion sources. In order to do this, the total quantities of the various fuels used are determined and the amounts used by the largest industries are found. The remaining sources are considered collectively as area sources, and their fuel use is based on the difference between the total and the amount consumed by the largest sources.

The total quantities of residual and distillate fuel oil consumed by industries were estimated using figures supplied by the local agency. Natural gas numbers were obtained from local suppliers who provided a breakdown by user category. Total coal consumption by industrial sources was based solely on questionnaire data or personal contacts made by the local agency.

The quantities of all fuels used by individual industries was found by the local and federal agencies and then subtracted from the totals to determine area source fuel use.

RESULTS: Coal and residual oil were used by industrial sources in the Study Area. The consumption of these fuels is summarized in Table 4.

Table 6 shows the relative contribution of each fuel to the total emissions from stationary fuel combustion. Industrial sources account for 33 percent of total sulfur oxide emissions from stationary fuel combustion, 50 percent of the particulates, 8 percent carbon monoxide, 22 percent of hydrocarbons, and 43 percent of nitrogen oxides.

Residential

METHODOLOGY: Natural gas, distillate fuel oil, and coal were the primary fuels used for residential home heating. There were homes heated by other fuels, but they represent a small percentage of the total. Data on the amount of natural gas used for domestic heating was supplied by the local utility companies and compared with the rapid survey technique of estimating the fuel used for home heating.[4] Distillate oil and coal consumption data were estimated based on data updated from the 1960 Census of Housing.

RESULTS: Emissions resulting from residential fuel combustion are relatively low for all pollutants. However, since coal is usually not burned efficiently in homes, carbon monoxide and hydrocarbons are high in relation to other residential fuel emissions. The contribution to total emissions from stationary fuel combustion by domestic heating was less than, 18 percent for particulates, 3 percent for sulfur oxides, 45 percent for carbon monoxides, 30 percent for hydrocarbons, and 12 percent for nitrogen oxides.

Commercial-Institutional

METHODOLOGY: Commercial and institutional establishments in the Study Area used distillate oil, natural gas, and coal. Data on the

TABLE 4 STATIONARY FUEL CONSUMPTION IN THE BILLINGS STUDY AREA, 1969

Fuel Type	Carbon County	Stillwater County	Yellowstone County	Total
Coal (tons/year)				
Steam-Electric Utility	--	--	72,000	72,000
Commercial-Institutional	615	512	512	1,639
Residential	899	749	749	2,398
Subtotal	1,514	1,261	73,261	76,037
Residual Oil (10^3 gallons/year)				
Steam-Electric Utility	--	--	756	756
Industry	--	--	9,700	9,700
Subtotal	--	--	10,456	10,456
Distillate Oil (10^3 gallons/year)				
Commercial-Institutional	92	123	300	515
Residential	138	185	451	751
Subtotal	230	308	751	1,289
Natural Gas (10^6 cubic feet/year)				
Steam-Electric	--	--	637	637
Industry	2	1	6,253	6,256
Commercial-Institutional	175	101	2,430	2,706
Residential	291	168	4,049	4,509
Subtotal	468	270	13,369	14,108

TABLE 5 AVERAGE CHEMICAL ANALYSIS OF FUELS CONSUMED IN THE BILLINGS STUDY AREA, 1969

Type Fuel	Type Source	% by Weight Ash Content	% by Weight Sulfur Content
Coal	Industrial	3.1	0.5
	Domestic-Commercial	3.1	0.5
Residual Fuel Oil	Industrial	N	3.0
	Domestic-Commercial	N	2.0
Distillate Fuel Oil	Industrial	N	0.32
	Domestic-Commercial	N	0.32

N = Negligible

TABLE 6 AIR POLLUTANT EMISSIONS FROM THE COMBUSTION OF FUELS IN STATIONARY SOURCES IN THE BILLINGS STUDY AREA

(Tons/Year)

Fuel	User Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Coal	Industrial	N	N	N	N	N
	Steam-Electric	684	71	18	7	720
	Residential	22	7	59	11	9
	Commercial and Institutional	15	6	40	8	6
Fuel Oil	Industrial	499	111	9	9	349
	Steam-Electric	300	3	N	1	39
	Residential	17	3	N	1	4
	Commercial and Institutional	11	3	N	N	18
Gas	Industrial	1	56	1	N	669
	Steam-Electric	N	4	N	N	124
	Residential	N	42	N	N	261
	Commercial and Institutional	N	25	N	N	156
GRAND TOTAL		1,550	330	130	40	2,360

total amounts of these fuels used in the area as well as the consumption at individual establishments were obtained from power companies, fuel associations, and local agencies.

RESULTS: The use of coal at commercial and institutional establishments accounted for 2 percent of the sulfur oxides, 10 percent of the particulates, 31 percent carbon monoxide, 20 percent hydrocarbons, 8 percent nitrogen oxides emitted from stationary fuel combustion sources.

TRANSPORTATION

Three types of transportation sources of pollution are considered in this survey, motor vehicles, aircraft, and railroads. Motor vehicles, which are by far the most significant source of pollutants in the transportation category, are further subdivided according to type of fuel, gasoline or diesel.

Motor Vehicles

About 1.9 million miles per day were traveled by motor vehicles in 1969 in the Billings Study Area. Table 7 shows the miles traveled for gasoline and diesel vehicles for each county in the Study Area. In the Billings Area approximately 55 million gallons of gasoline and 3 million gallons of diesel fuel were consumed for highway purposes in 1969.

Vehicle miles per county were calculated from Montana averages for annual miles of travel per vehicle and the number of vehicles registered in the county. The vehicle miles were then apportioned by grid using

maps of vehicle mileage on the primary roads in the counties supplied by the Montana Highway Commission.

The contribution to the total vehicle pollution by diesel powered vehicles was determined by assuming that approximately 2.3 percent of the total vehicle miles traveled were by diesel powered vehicles. This was checked by estimating the diesel fuel consumption in each county.

Emissions from motor vehicles are a function of the speed at which the vehicle travels. Average speeds of 10-20 mph were assumed for downtown areas, 20-30 mph for residential areas and 30-45 mph for the rural areas to calculate vehicle emissions.

From all transportation sources, motor vehicles accounted for 47 percent of the sulfur oxides, 28 percent of the particulate, 82 percent of the carbon monoxide, 58 percent of the hydrocarbons, and 60 percent of the nitrogen oxides. Gasoline powered motor vehicles contributed a greater percent of all pollutants than diesel powered motor vehicles. Emissions from transportation sources are summarized in Table 8.

Aircraft

Table 9 shows the air traffic activity at the airport in the Study Area. An estimate of the number of flights by engine type was supplied by the traffic controller at the airport and the Civil Aeronautics Board and summarized in Table 9.

The air pollutant emissions from aircraft include all phases of operation (taxi, take off, climb out, landings) that take place below an arbitrarily chosen altitude of 3,500 feet. Emissions at cruise altitude (above 3,500 feet) were not considered in this inventory.

TABLE 7 VEHICLE MILES OF TRAVEL FOR ROAD VEHICLES IN BILLINGS STUDY AREA PER DAY, 1969

Jurisdiction	Gasoline Vehicle Miles	Diesel Vehicle Miles	Total
Yellowstone	1,551,000	35,000	1,586,000
Stillwater	118,000	3,000	121,000
Carbon	171,000	4,000	175,000
TOTAL	1,840,000	42,000	1,882,000

TABLE 8 SUMMARY OF AIR POLLUTANT EMISSIONS FROM TRANSPORTATION SOURCES

(Tons/Year)

Source	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbon	Nitrogen Oxides
Road Vehicles					
Gasoline	210	280	45,250	3,600	3,010
Diesel	70	180	100	220	360
Evaporative Losses*				2,970	
Subtotal	280	460	45,350	6,790	3,370
Aircraft					
Jet	N	260	260	200	180
Piston	N	40	7,980	1,510	370
Turboprop	N	10	20	10	10
Subtotal	N	310	8,260	1,720	560
Railroads	310	860	470	1,060	1,730
GRAND TOTAL	590	1,630	54,080	6,600	5,660

*Evaporation not included in grand total.

TABLE 9 AIR TRAFFIC ACTIVITY IN THE BILLINGS STUDY AREA

1969 (100 Flights/Year)

Type Aircraft	Billings
Jet 1 Engine	21
Jet 2 Engine	12
Jet 4 Engine	120
Fan Jet 2 Engine	10
Fan Jet 3 Engine	0
Fan Jet 4 Engine	100
Turboprop 2 Engine	50
Turboprop 4 Engine	44
Piston 1 Engine	606
Piston 2 Engine	202
Piston 4 Engine	91

Emissions from aircraft are included in Table 8. Aircraft is a significant contributor to carbon monoxide, hydrocarbon and nitrogen oxides emitted from transportation sources.

Railroads

Railroad operations (mainly locomotive) consume about 16 million gallons of diesel fuel per year within the Billings Study Area. The majority of this fuel is consumed during switching operations.

Emissions from railroad operations are contained in Table 8.

SOLID WASTE DISPOSAL

Approximately 171,500 tons of refuse were generated during 1969 within the Study Area. Table 10 presents a solid waste balance for the Study Area, showing the various methods of disposal and quantities disposed of by each method.

All three counties had on-site incineration and open burning. The majority of municipal refuse was disposed of in landfills or non-burning dumps. A refuse disposal rate of 10 pounds/capita-day (7 pounds residential, 3 pounds industrial) was used for Yellowstone County. In Carbon and Stillwater Counties a rate of 7 pounds/capita-day was used due to lack of industry in these areas.[5]

Table 11 presents the air pollutant emissions from solid waste disposal. This source does not contribute significantly to the total emissions for the Study Area.

TABLE 10 SOLID WASTE DISPOSAL PRACTICES, 1969

Jurisdiction	Incineration (tons)	Open Burning (tons)	Landfill (tons)	Total Generated (tons)
Carbon	647	4,328	3,865	8,840
Stillwater	360	2,800	2,450	5,610
Yellowstone	45,070	550	111,380	157,000
TOTAL	46,077	7,678	117,695	171,450

TABLE 11 AIR POLLUTANT EMISSIONS FROM SOLID WASTE DISPOSAL, 1969

(Tons/Year)

Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Incineration					
Municipal	0	0	0	0	0
On-site	20	10	250	10	50
Subtotal	20	10	250	10	50
Open Burning					
On-site	N	40	220	90	30
Dump	0	0	0	0	0
Subtotal	N	40	220	90	30
GRAND TOTAL	20	50	470	100	80

INDUSTRIAL PROCESSES

The Study Area has relatively few heavy industrial complexes. From an air pollution standpoint, one sugar beet refinery, three petroleum refineries, five asphalt batching plants, one sulfur plant, two meat packing plants, and several grain elevators were the most significant process sources. Table 12 presents a summary of the emissions.

EVAPORATIVE LOSSES

Three source categories were considered for evaporative losses--automobiles, gasoline storage and handling, and the consumption of solvents. The hydrocarbon emissions from all sources by evaporative losses are shown in Table 13.

Automobiles

Automobile evaporative losses include gas tank and carburetor evaporation and engine crankcase blowby. Since 1963, most new automobiles were equipped with positive crankcase ventilation (PCV) valves that reduced hydrocarbon emissions from the crankcase by about 90 percent. Since 1968 the closed crankcase ventilation system required on new cars has reduced emissions by an additional amount.

Since there exists a lag time in automobile replacement, it was assumed that a percentage of the automobiles were not equipped with PCV valves or closed crankcase ventilation.

The hydrocarbon emissions from automobiles were calculated from the number of gallons of gasoline used in each county and apportioned onto grids by vehicle mileage using the same methods as for motor vehicles

TABLE 12 AIR POLLUTANT EMISSIONS FROM THE MOST SIGNIFICANT INDUSTRIAL PROCESSES*, 1969

(Tons/Year)

Industry	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Grain Elevators	--	300	--	--	--
Meat Packing	--	450	10	--	--
Asphalt Batching	--	50	--	--	--
Petroleum Refining	17,850	9,960	57,600	12,660	6,140
Oil Rerefining	--	--	20	--	--
TOTAL	17,850	10,760	57,630	12,660	6,140

*If only one individual company is involved information is withheld to avoid divulging confidential information.

discussed earlier. Evaporative losses from automobiles accounted for 12.5 percent of the total hydrocarbon emissions from evaporative losses in the Study Area.

Gasoline Storage and Handling

There are four major points (excluding evaporation from the motor vehicle) of hydrocarbon emissions in the storage and handling of gasoline.

They are:

1. Breathing and filling losses from storage tanks
2. Filling losses from loading tank conveyances
3. Filling losses from loading underground storage tanks at service stations.
4. Spillage and filling losses in filling automobile gas tanks at service stations.

The evaporative losses from storage and the subsequent handling of gasoline and diesel fuel accounted for 3 percent of the total evaporative losses.

Consumption of Solvents

This category included the consumption of solvents at dry cleaning plants. Organic solvents emitted from these operations were determined by assuming an emission rate of 2 pounds/capita/year for any cleaning plants. The consumption of solvents by this category accounted for only one percent of the hydrocarbon emissions in the Study Area.

TABLE 13 SUMMARY OF HYDROCARBON EMISSIONS

FROM EVAPORATIVE LOSSES, 1969

Type of Source	Hydrocarbon Emissions Tons/Year
Gasoline Storage and Handling	740
Industrial Solvent Evaporation	N
Dry Cleaning	210
Other	N
Automobile	2,970
TOTAL	3,920

EMISSIONS BY JURISDICTION

The previous section presented the air pollutant emissions by source category. In order to show the contribution of each county to the pollution in the entire Study Area, their emissions are summarized in Tables 14 through 16.

As can be expected, the most heavily populated and industrialized counties contribute the most total air pollutants regardless of the category. Note that due to rounding, totals may not add in Tables 14-16.

EMISSIONS BY GRID

For the purpose of defining the geographical variation of air pollutant emissions in the Study Area, the resulting emissions were apportioned on the grid coordinate system. The emissions were divided into two source groups--point and area sources. Twenty-one point sources are identified individually with respect to location and emissions. Each of the point sources emitted a significant amount of pounds per average annual day of any pollutant in relation to most sources of pollution in the Study Area.

CONTRIBUTIONS OF POINT AND AREA SOURCES

Figure 5 shows the location of all point sources in the area. Collectively, the 21 point sources account for 84 percent of the particulates, 59 percent of the hydrocarbons, 60 percent of the carbon monoxide, 94 percent of the sulfur oxides, and 62 percent of the nitrogen oxides.

TABLE 14 SUMMARY OF AIR POLLUTANT EMISSIONS IN CARBON COUNTY*

Tons/Year

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation					
Road Vehicles	9	15	1,101	101	113
Other	30	84	46	104	171
Subtotal	40	100	1,147	206	284
Stationary Fuel Combustion					
Industry	N	N	N	N	N
Residential	11	6	22	4	21
Commercial and Institutional	7	4	15	3	15
Subtotal	19	10	38	7	37
Refuse Disposal					
Incineration	N	3	14	N	N
Open Burning	2	34	183	64	23
Subtotal	2	37	198	65	24
Process Losses	N	102	604	120	11
Evaporative Losses	--	--	--	183	--
GRAND TOTAL	60	250	1,990	580	360

*Totals may not add due to rounding.

TABLE 15 SUMMARY OF AIR POLLUTANT EMISSIONS IN STILLWATER COUNTY

Tons/Year

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Road Vehicles	14	25	1,733	160	182
Other	31	85	46	106	173
Subtotal	46	110	1,780	266	355
Stationary Fuel Combustion					
Industry	N	N	N	N	N
Residential	11	4	18	4	13
Commercial and Institutional	7	3	12	2	12
Subtotal	19	8	31	6	26
Refuse Disposal					
Incineration	N	1	7	N	N
Open Burning	N	N	13	17	4
Subtotal	N	1	21	17	4
Process Losses	N	125	737	147	14
Evaporative Losses	--	--	--	215	--
GRAND TOTAL	70	250	2,770	650	400

TABLE 16 SUMMARY OF AIR POLLUTANT EMISSIONS IN YELLOWSTONE COUNTY

Tons/Year

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Road Vehicles	253	422	42,512	3,559	3,077
Other	249	993	8,633	2,558	1,956
Subtotal	502	1,416	51,146	6,117	5,033
Stationary Fuel Combustion					
Industry	500	167	10	9	1,018
Steam-Electric Utility	3,470	1,054	83	37	3,307
Residential	18	42	19	4	240
Commercial and Institutional	12	27	13	2	153
Subtotal	4,001	1,292	128	54	4,719
Refuse Disposal					
Incineration	22	4	229	11	45
Open Burning	N	4	23	8	3
Subtotal	23	8	253	19	49
Process Losses	22,816	12,094	58,045	12,765	8,297
Evaporative Losses	--	--	--	3,521	--
GRAND TOTAL	27,340	14,810	109,570	22,480	18,100

TABLE 17 SUMMARY OF AIR POLLUTANT EMISSIONS FROM POINT SOURCES IN THE BILLINGS STUDY AREA, 1969
TONS/DAY

ID	GR	HC	VC	SOX			PART			CO			HC			NOX		
				S	W	A	S	W	A	S	W	A	S	W	A	S	W	A
2	5	1190	70765	14.0	14.1	14.1	18.99	19.00	19.00	54.79	54.80	54.80	14.09	14.10	14.10	10.89	10.91	10.90
2	5	1190	70765	6.7	6.7	6.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5	1190	70795	0.0	0.0	0.0	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5	1160	70755	0.0	0.0	0.0	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	9	1155	70720	9.5	9.5	9.5	2.89	2.89	2.88	0.23	0.23	0.22	0.10	0.10	0.10	9.09	9.09	9.06
2	10	1160	70715	0.0	0.0	0.0	0.82	0.90	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.03	0.58
2	10	1145	70736	0.0	0.0	0.0	0.00	0.04	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.52	0.29
2	10	1145	70734	0.0	0.0	0.0	1.22	1.27	1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.29
2	10	1097	707 0	0.0	0.0	0.0	0.00	0.00	0.00	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.02	0.01
2	10	1140	70741	0.0	0.0	0.0	0.00	0.00	0.00	0.04	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00
2	10	1128	70722	0.0	0.0	0.0	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	10	1128	70722	0.0	0.0	0.0	0.34	0.34	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	10	1128	70722	0.0	0.0	0.0	0.08	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	10	1128	70722	0.0	0.0	0.0	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	10	1145	70730	10.7	11.6	11.3	1.47	1.90	1.72	102.99	103.03	103.02	11.79	11.83	11.82	0.95	2.28	1.70
2	11	1097	707 5	0.0	0.0	0.0	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	11	1097	707 5	0.0	0.0	0.0	0.34	0.34	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	16	1075	70698	0.0	0.0	0.0	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	16	1035	70675	0.0	0.0	0.0	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	25	925	70590	23.9	24.0	24.0	6.79	6.82	6.81	0.00	0.00	0.00	8.79	8.79	8.79	4.96	5.30	5.15

TABLE 18 SUMMARY OF AIR POLLUTANT EMISSIONS FROM ALL SOURCES IN THE BILLINGS STUDY AREA, 1969
TONS/DAY

		SOX			PART			CO			HC			NOX		
GRID	AREA	S	W	A	S	W	A	S	W	A	S	W	A	S	W	A
1	617.7	0.4	0.5	0.5	1.2	1.2	1.2	3.2	4.1	3.6	1.9	2.1	2.0	2.5	2.6	2.6
2	617.7	0.0	0.1	0.0	0.1	0.2	0.2	1.9	2.5	2.1	0.5	0.6	0.5	0.3	0.4	0.4
3	617.7	0.0	0.0	0.0	0.1	0.2	0.2	1.0	1.1	1.1	0.2	0.2	0.2	0.1	0.1	0.1
4	154.4	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.7	2.3	0.4	0.5	0.4	0.2	0.3	0.2
5	9.6	21.0	21.1	21.0	19.2	19.2	19.2	59.6	61.3	60.2	15.0	15.3	15.1	11.3	11.7	11.5
6	9.6	0.0	0.0	0.0	0.8	0.8	0.8	22.9	23.0	23.0	4.7	4.7	4.7	1.6	1.6	1.6
7	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.4	0.1	0.1	0.1	0.0	0.1	0.0
8	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.4	0.1	0.1	0.1	0.0	0.1	0.0
9	9.6	9.6	9.6	9.5	2.9	2.9	2.9	1.0	1.3	1.1	0.2	0.3	0.2	9.2	9.2	9.2
10	9.6	11.3	13.0	12.2	4.7	5.7	5.2	157.5	177.2	164.9	21.5	24.5	22.7	5.4	11.7	8.7
11	9.6	0.2	0.6	0.4	0.6	0.8	0.7	21.3	29.0	24.2	3.1	4.1	3.5	1.3	2.6	2.0
12	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.8	0.6	0.1	0.1	0.1	0.0	0.1	0.1
13	38.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	38.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	38.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	38.6	0.1	0.1	0.1	0.2	0.3	0.3	0.7	0.9	0.8	0.3	0.4	0.3	0.4	0.4	0.4
17	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	9.6	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3
20	9.6	0.1	0.2	0.2	0.2	0.3	0.2	10.4	14.1	11.8	1.7	2.2	1.9	0.9	1.2	1.0
21	38.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	154.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
23	154.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
24	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	9.6	24.0	24.1	24.0	6.9	6.9	6.9	3.5	4.7	3.9	9.5	9.7	9.6	5.4	5.9	5.6

TABLE 18 SUMMARY OF AIR POLLUTANT EMISSIONS FROM ALL SOURCES (cont.)

26	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.3	0.0	0.1	0.1	0.0	0.0	0.0
28	38.6	0.0	0.0	0.0	0.1	0.1	0.1	0.9	1.2	1.0	0.2	0.3	0.2	0.2	0.2	0.2
29	38.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	38.6	0.0	0.0	0.0	0.0	0.1	0.0	0.8	1.1	0.9	0.2	0.2	0.2	0.1	0.2	0.1
31	617.7	0.1	0.2	0.1	0.4	0.5	0.4	4.2	5.4	4.7	1.2	1.4	1.3	0.7	1.0	0.8
32	154.4	0.0	0.0	0.0	0.1	0.1	0.1	0.9	1.2	1.0	0.3	0.3	0.3	0.2	0.3	0.3
33	154.4	0.0	0.1	0.0	0.1	0.1	0.1	1.0	1.2	1.1	0.3	0.3	0.3	0.2	0.3	0.3
34	617.7	0.0	0.1	0.0	0.2	0.3	0.2	1.3	1.4	1.4	0.5	0.6	0.5	0.1	0.2	0.1
35	617.7	0.0	0.0	0.0	0.2	0.2	0.2	1.2	1.4	1.3	0.3	0.3	0.3	0.1	0.2	0.2
TOTAL		68.7	71.4	70.2	40.2	41.7	41.0	299.0	339.3	314.2	64.3	70.4	66.6	42.6	52.3	47.5

Each source is identified by source category, grid number, and horizontal and vertical coordinates.

Plant Identification Key

1 = commercial source

2 = industrial

3 = institutional

5 = dump

7 = airport

The emissions of sulfur oxides, particulates, carbon monoxide, hydrocarbons, and nitrogen oxides are shown for an average annual day, average winter day (December, January, February) and average summer day (June, July, August). The appendix presents the method of calculating these three averages.

Area sources are sources of emissions that are insignificant by themselves, but as a group may emit a large portion of the area's total pollution. Examples of area sources are motor vehicles, residences, light commercial and industrial establishments and backyard burning. The emissions from area sources have been added to that for point sources to obtain total emissions from all sources by grid, as shown in Table 18. The emissions from all sources are also shown for an annual average winter and summer day.

EMISSION DENSITIES

In order to provide a visual representation of the emissions of pollutants by grids, emission density maps have been prepared. Emission densities were obtained by summarizing the annual area and point source emissions for each grid and dividing this total by the land area of the grid. Figures six to ten show the variation of emission

densities for the respective grids throughout the Study Area. As expected the emissions generally follow the pattern and degree of urbanization. Emission densities for CO and HC are higher in the grids with the higher populations and corresponding higher vehicular activity.

Sulfur oxides, particulates, and nitrogen oxide emission densities are highest in the grids of higher populations and industry, corresponding to greater stationary fuel combustion and vehicular activity.

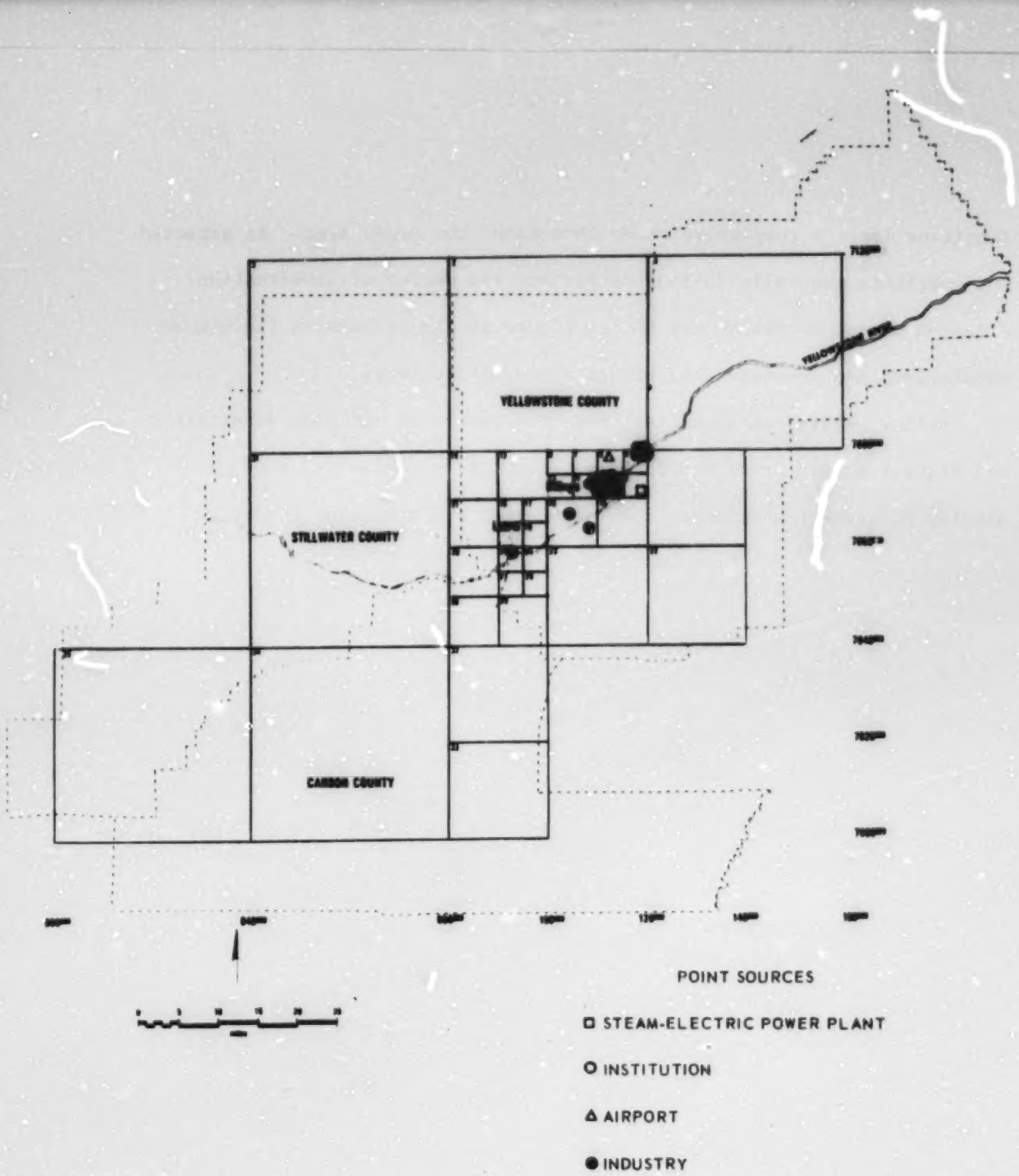

Figure 5. Point source locations in the Billings study area.

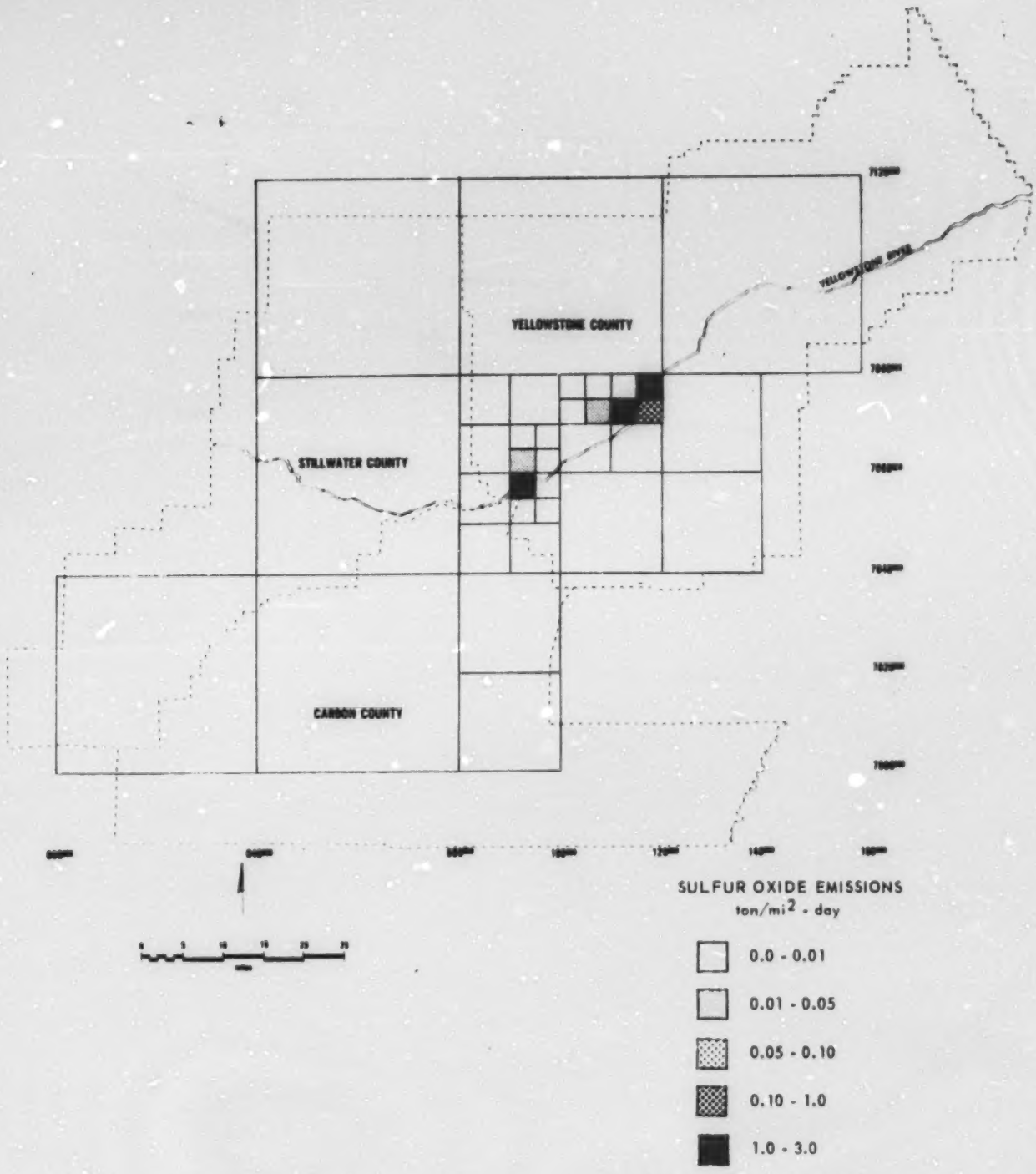

Figure 6. Sulfur oxide emission density from all sources in the Billings study area.

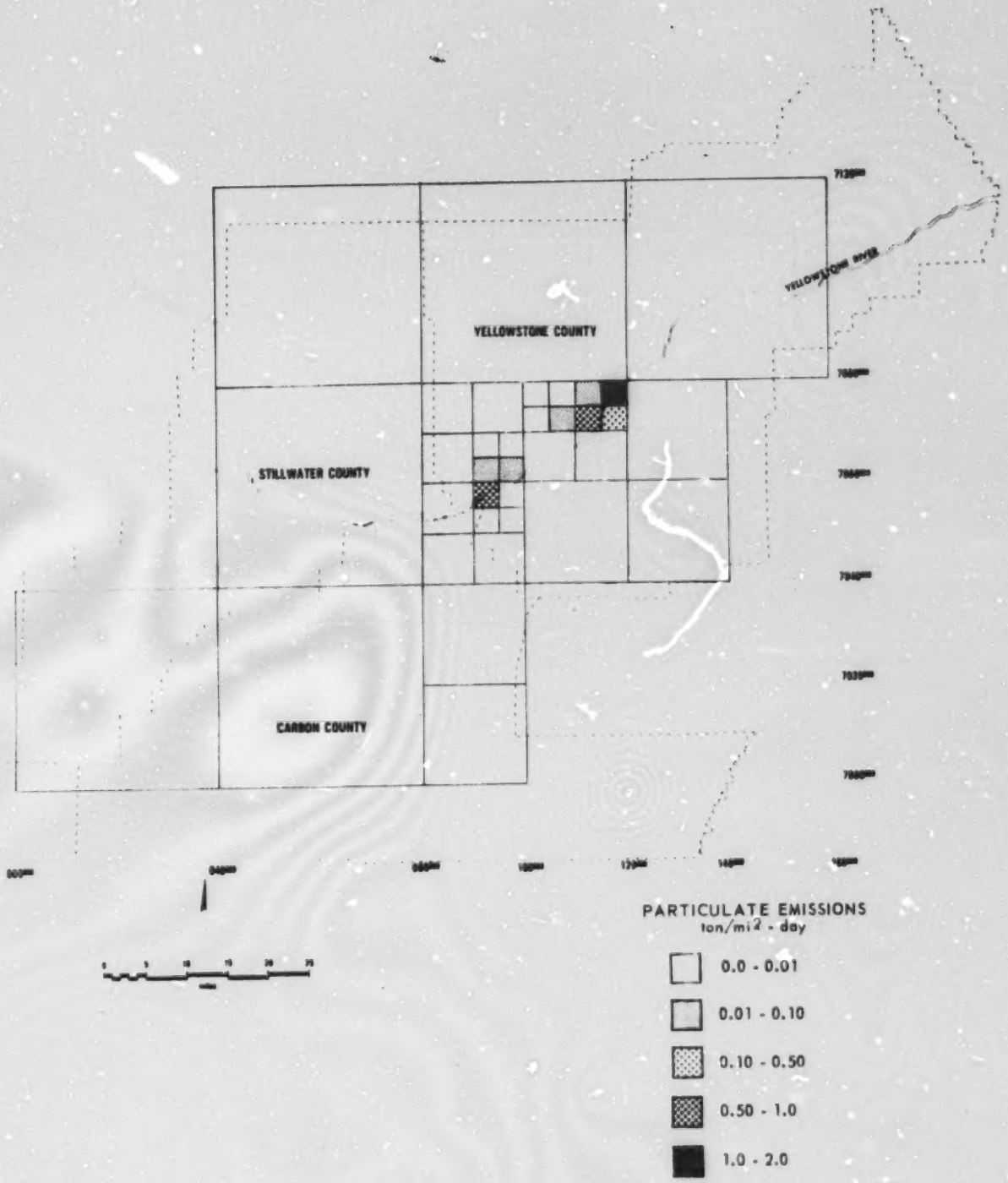

Figure 7. Particulate emission density from all sources in the Billings study area.

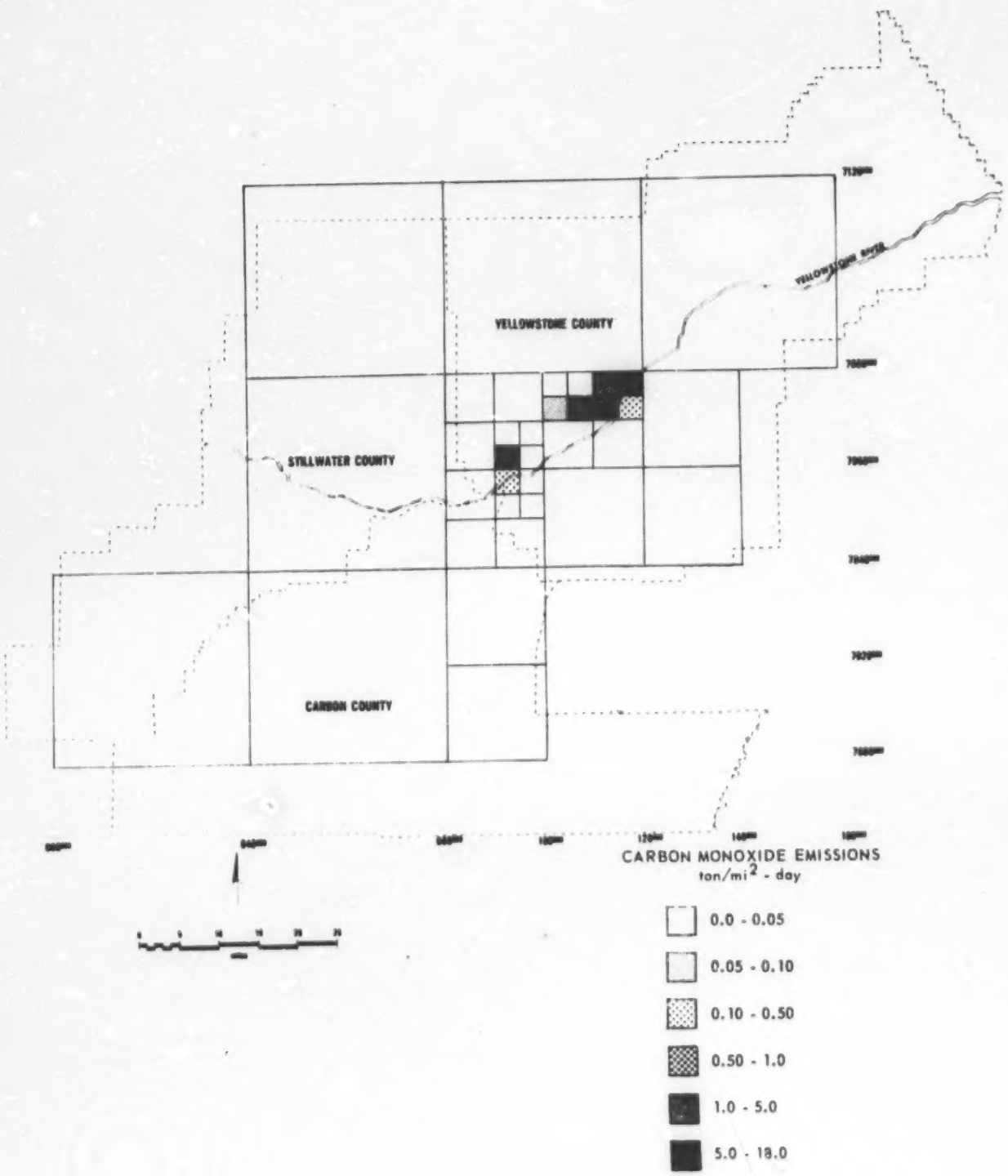

Figure 8. Carbon monoxide emission density from all sources in the Billings study area.

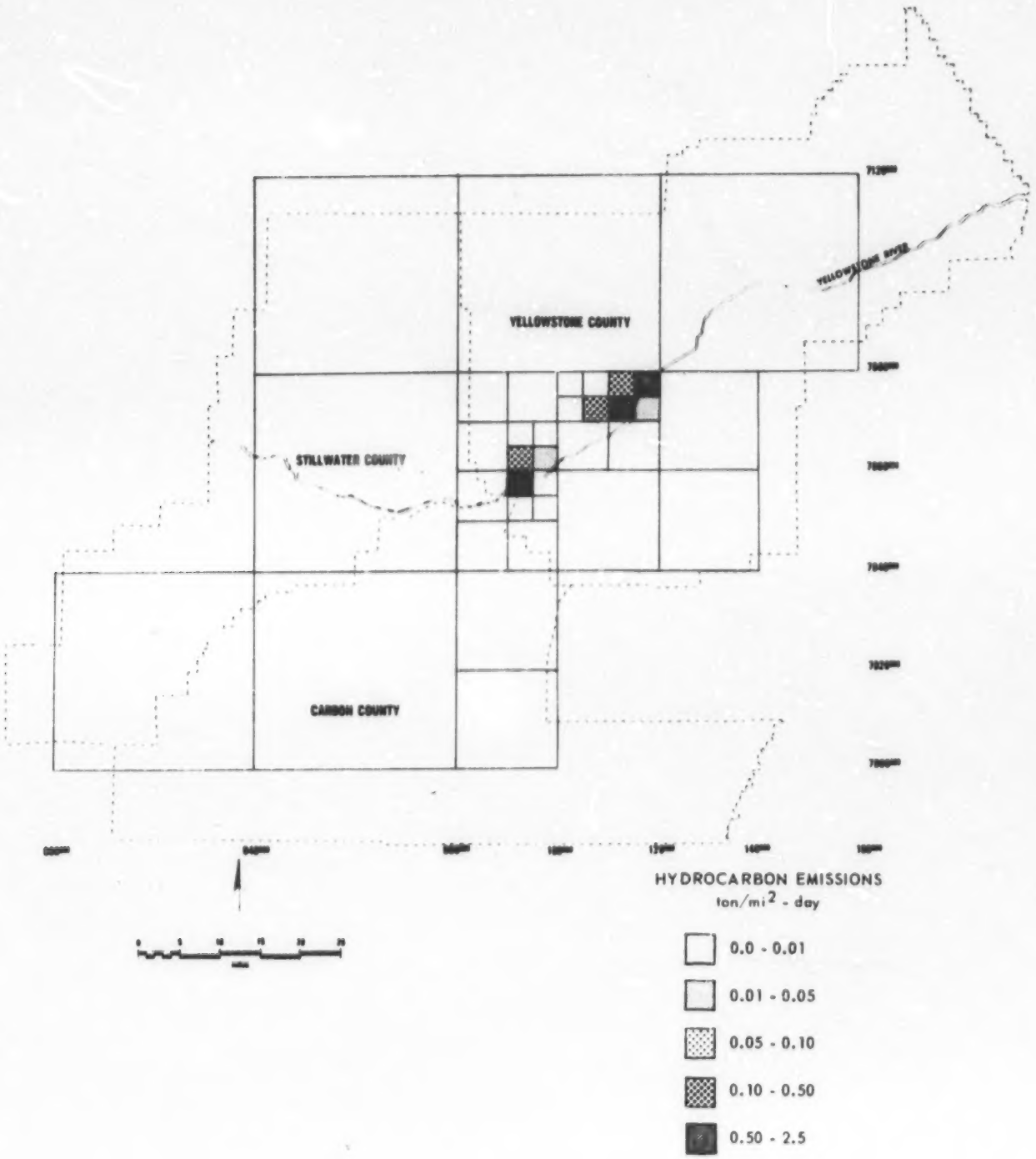

Figure 9. Hydrocarbon emission density from all sources in the Billings study area.

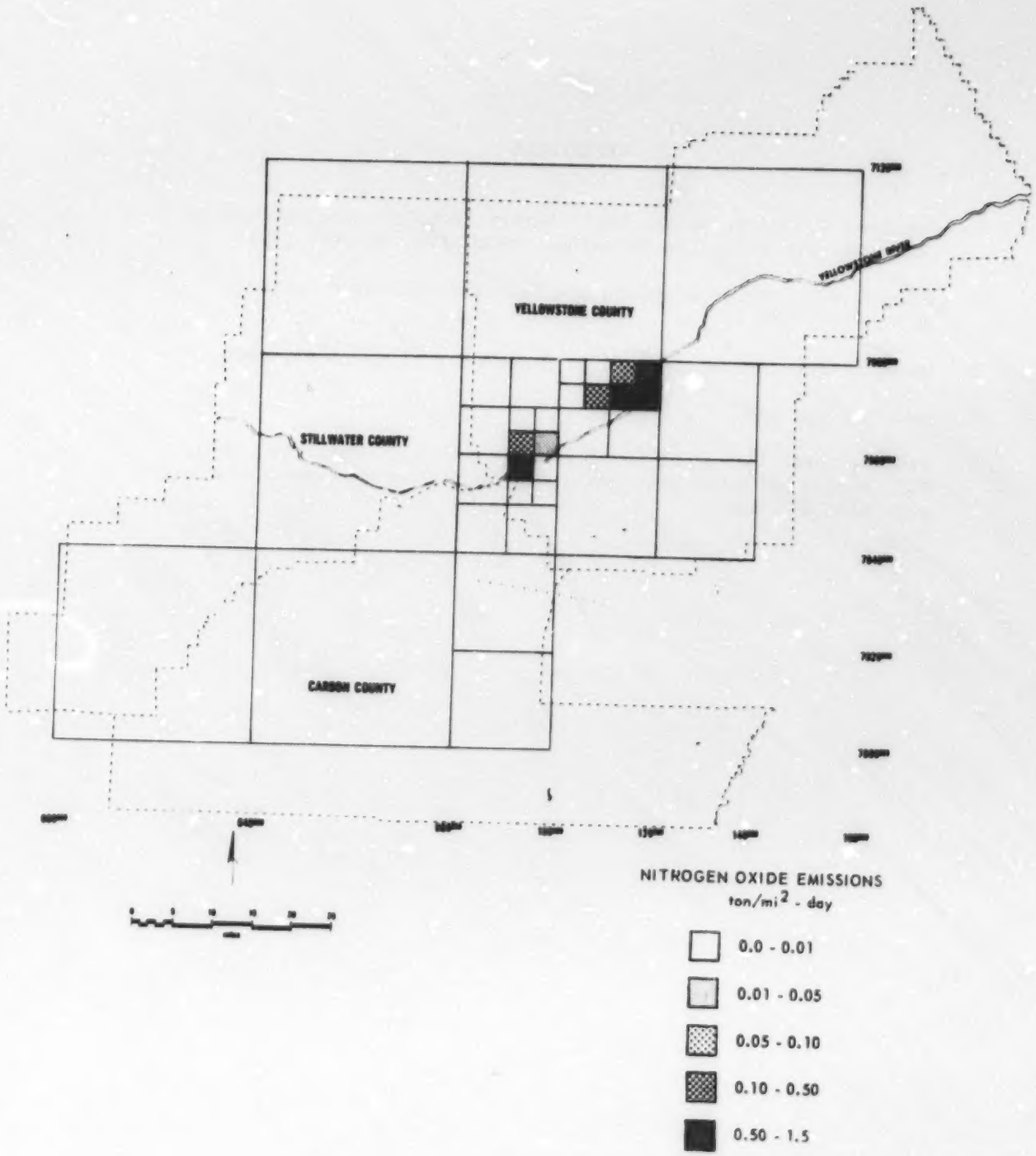

Figure 10. Nitrogen oxide emissions from all sources in the Billings study area.

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2. Duprey, R.L., Compilation of Air Pollutant Emission Factors, DHEW, PHS, 1968.

3. Local Climatoligical Data, U.S. Department of Commerce, 1969.

4. Ozolins, op. cit., p. 43-45.

5. 1968 National Survey of Community Solid Wastes Practices, DHEW, PHS, Bureau of Solid Waste Management and Private communication with NIAPEC Branch.

APPENDIX A

METHOD FOR CALCULATING SUMMER, WINTER AND ANNUAL AVERAGE EMISSIONS FOR FUEL CONSUMPTION IN STATIONARY SOURCES

YEARLY AVERAGE (A)

$$A = \frac{\text{Fuel Consumed} \times \text{Emission Factor (E. F.)}}{\text{Days of Operation}}$$

e.g. A plant consumed 100,000 tons of coal in 1967 while operating 365 days. The total degree days for the area was 4,800 and 2,800 for the three winter months. The plant was estimated to use 15 percent of the fuel for space heating and 85 percent for process heating. From this information, the annual average emission for carbon monoxide would be the following:

$$A = \frac{100{,}000 \text{ Tons/year} \times 3 \text{ lbs. CO/Ton coal}}{365 \text{ Days/year} \times 2{,}000 \text{ lb./Ton}}$$

$$A = 0.41 \text{ Ton/Day}$$

WINTER AVERAGE (W)

$$W = \frac{\text{Fuel Consumed} \times \text{E.F.}}{\text{Days of Winter Operation}} \times \frac{\text{Winter Degree Days}}{\text{Total Degree Days}} \times \text{\% Fuel Used for space heating}$$

$$+ \frac{\text{Fuel Consumed} \times \text{E.F.}}{365} \times \text{\% Fuel used for process heating}$$

$$W = \left[\frac{100{,}000 \times 2{,}800}{90 \times 4{,}800} \times 0.15 + \frac{100{,}000}{365} \times 0.85\right] \frac{3}{2{,}000}$$

$$W = 0.49 \text{ Ton/Day}$$

SUMMER AVERAGE (S)

$$S = \frac{\text{Fuel Consumed} \times \text{E.F.}}{\text{Days of Summer Operation}} \times \frac{\text{Summer Degree Days}}{\text{Total Degree Days}} \times \text{\% Fuel Used for space heating}$$

$$+ \frac{\text{Fuel Consumed} \times \text{E.F.}}{365} \times \text{\% Fuel used for process heating}$$

$$S = \left[\frac{100{,}000}{90} \times \frac{0}{4{,}800} \times 0.15 + \frac{100{,}000}{365} \times 0.85\right] \frac{3}{2{,}000}$$

$$S = 0.35 \text{ Ton/Day}$$

APPENDIX B
METRIC CONVERSION FACTORS

Multiply	By.	To Obtain
Feet	0.3048	Meters
Miles	1609	Meters
Square Feet	0.0929	Square meters
Square Miles	2.59	Square kilometers
Pounds	453.6	Grams
Pounds	$453.6/10^4$	Tons (metric)
Tons (metric)	1.103	Tons (short)
Tons (short)	907.2	Kilograms
Tons (short)	.9072	Tons (metric)

To Obtain	By	Divide